In-situ Cryogenic Single-Event Effects Testing of High-Speed SiGe BiCMOS Devices

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6th International Planetary Probe Workshop

Atlanta, Georgia, USA

Session VI: Extreme Environments

June 25, 2008

Motivation

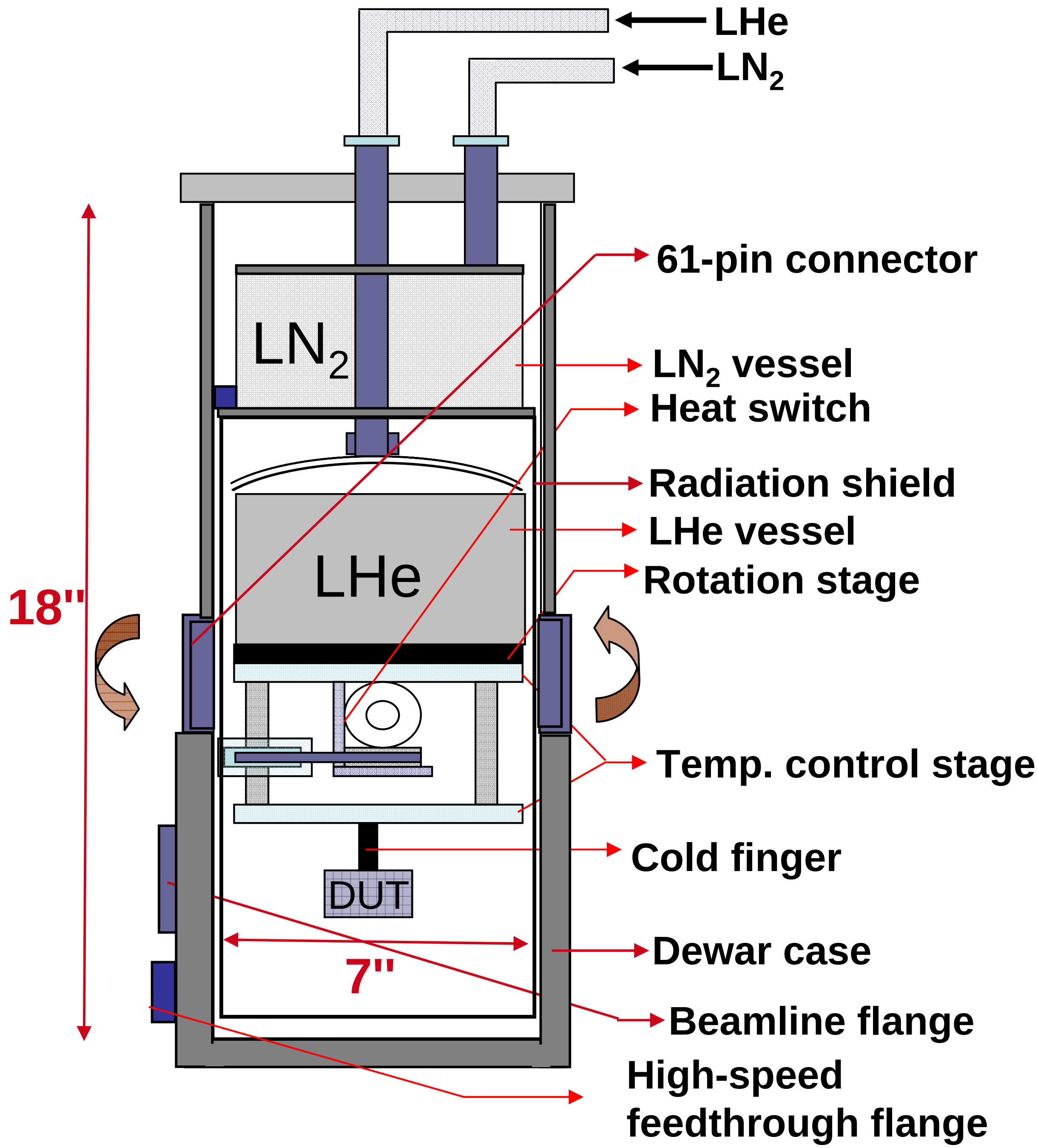
- Primary considerations for systems targeted at long term operation in distant, extreme environments
    - Weight
    - Power consumption
    - Tolerance of extreme temperatures AND radiation
- Application of advanced technologies
    - Design techniques can address wide temperature range operation
    - RHBD techniques can address radiation
    - Reduce requirements for environmental controls
- Need to characterize response - cryo + radiation
    - Very low temperatures
    - Little data available for rad effects at low temp; existing data indicates reduced temperature may exacerbate SE effects
    - Define worst case for designers
    - Validate models and hardware designs with test data

Approach

- Establish a new test system to measure single-event (SE) effects at cryogenic temperatures (cryo)
    - Portable
    - Compatible with multiple test facilities
    - Suitable for multiple technologies and operating speeds
- Apply test system to characterize the response of SiGe BiCMOS devices and circuits
    - Generate heavy-ion experimental data at cryo to aid future NASA missions
    - Basic device level testing to provide models to use in designs
    - Circuit testing to validate designs

A Unique Dewar

- Dual (LHe & LN_2) use Dewar
- Easily portable; weighs about 20 lbs
- Beam facility “flange-adaptable”
- Device under test (DUT) can be rotated about a vertical axis *in-situ* and under vacuum
- Heat switch provided for controlling DUT temperature
- Test-circuit-adaptable “cold-finger”

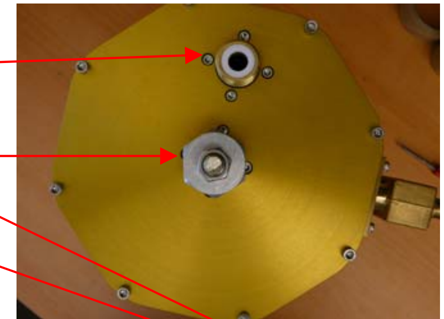


A Closer Look..

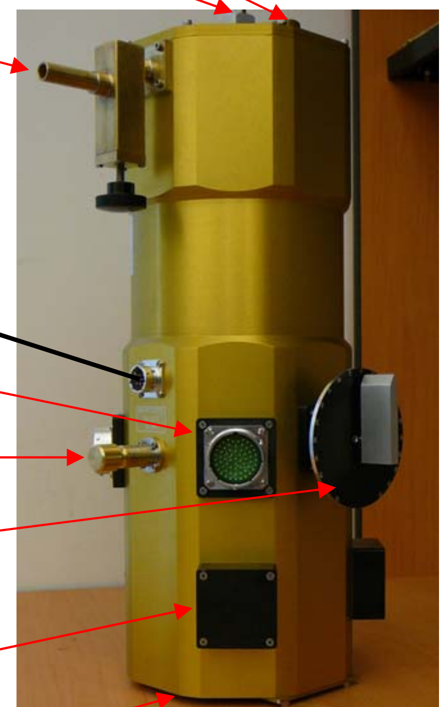
Temperature controller

LN$_2$ fill port

LHe fill port

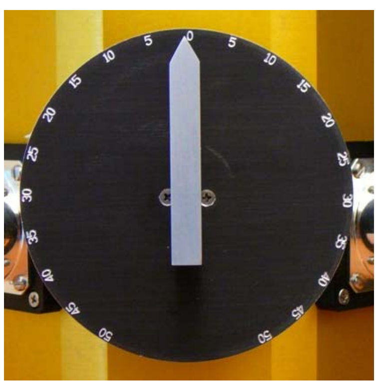


Vacuum port



61-pin connector
(1 of 4)

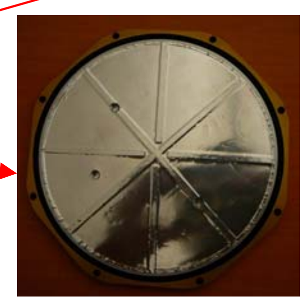
Heat switch control knob



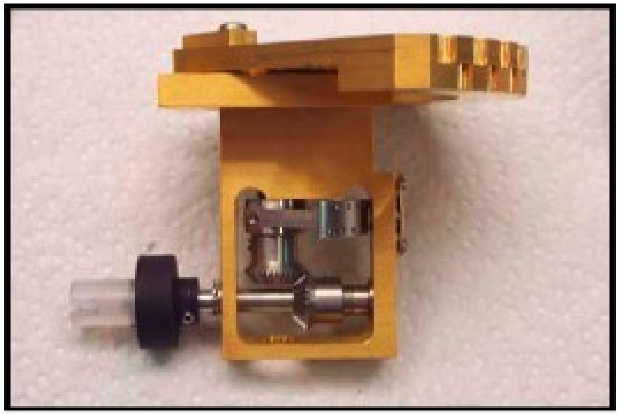
Rotation stage
control knob

Blank ports (1 of 2, for
high-speed feedthroughs)

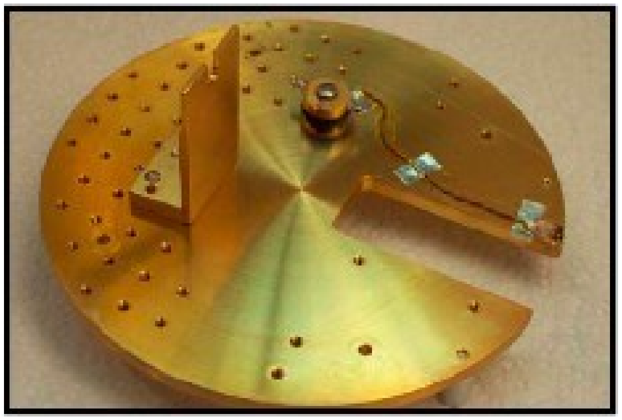
Cover plate +
radiation shield



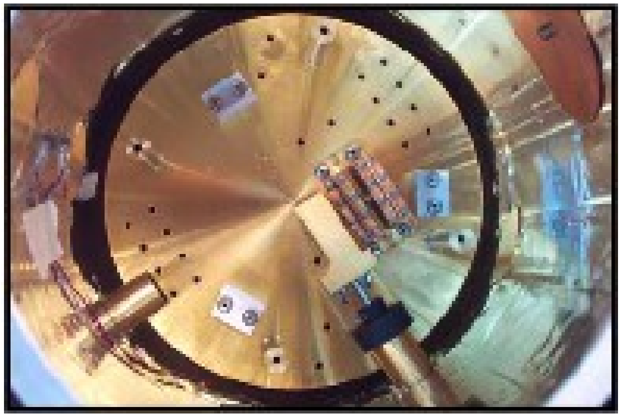
Key Dewar Modules


Rotation stage assembly

- Rotation in 5° increments, about a vertical axis
- A total rotation span of 68°

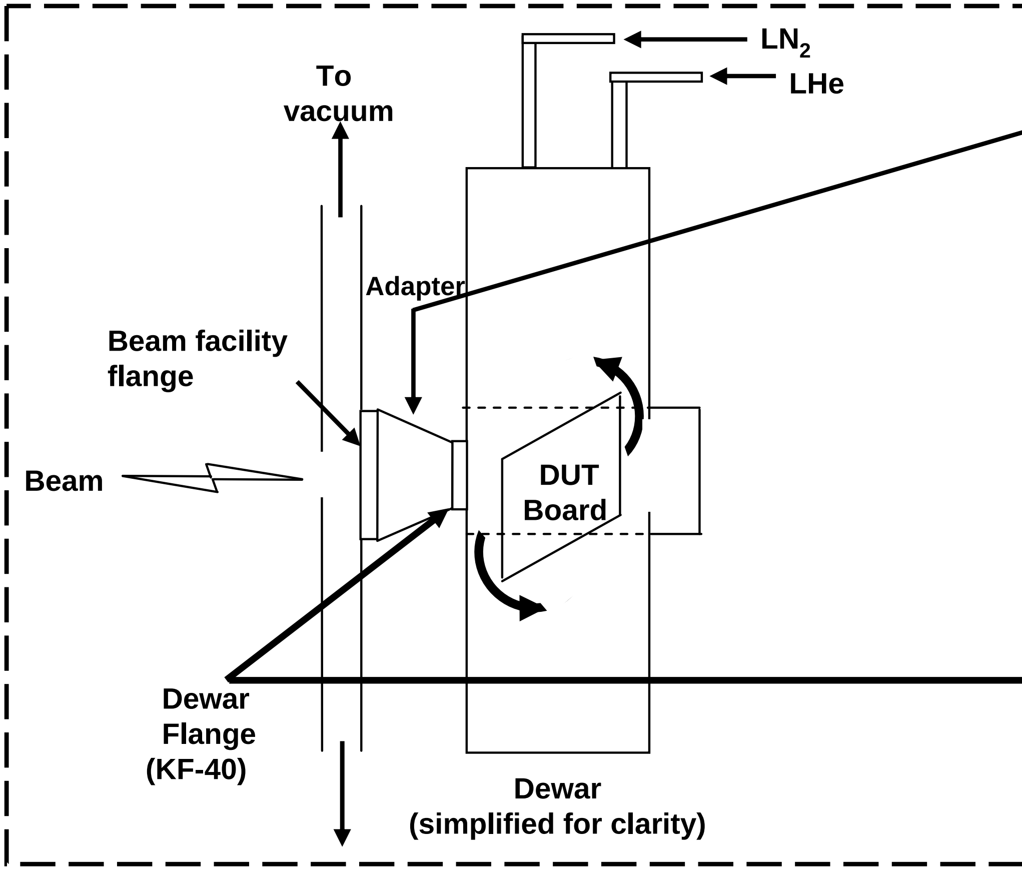

Cold plate + heater

- Dewar cold plate would be at or very close to cryogen temperature
- Power output to heater to be controlled by temperature controller

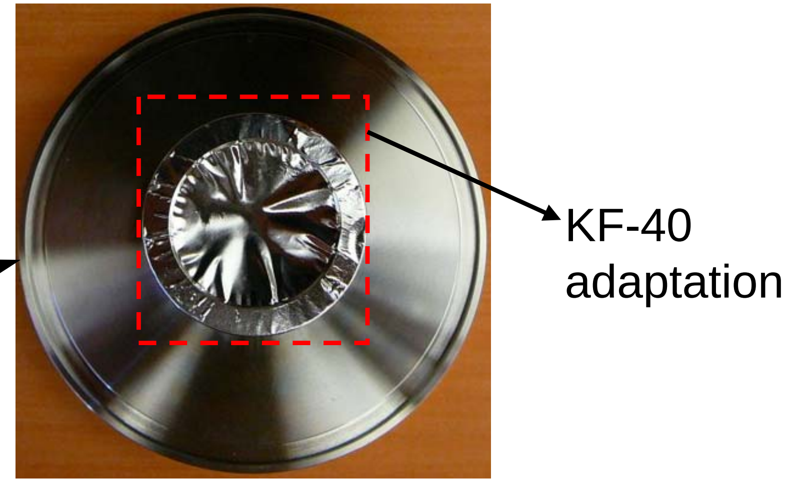

Cold plate + heat switch

- Position of heat switch determines the amount of heat delivered
- 25 turns on the control knob represent 0 through 100% heat delivered

Dewar Flange & Adaptations



Dewar mounting at beam facility

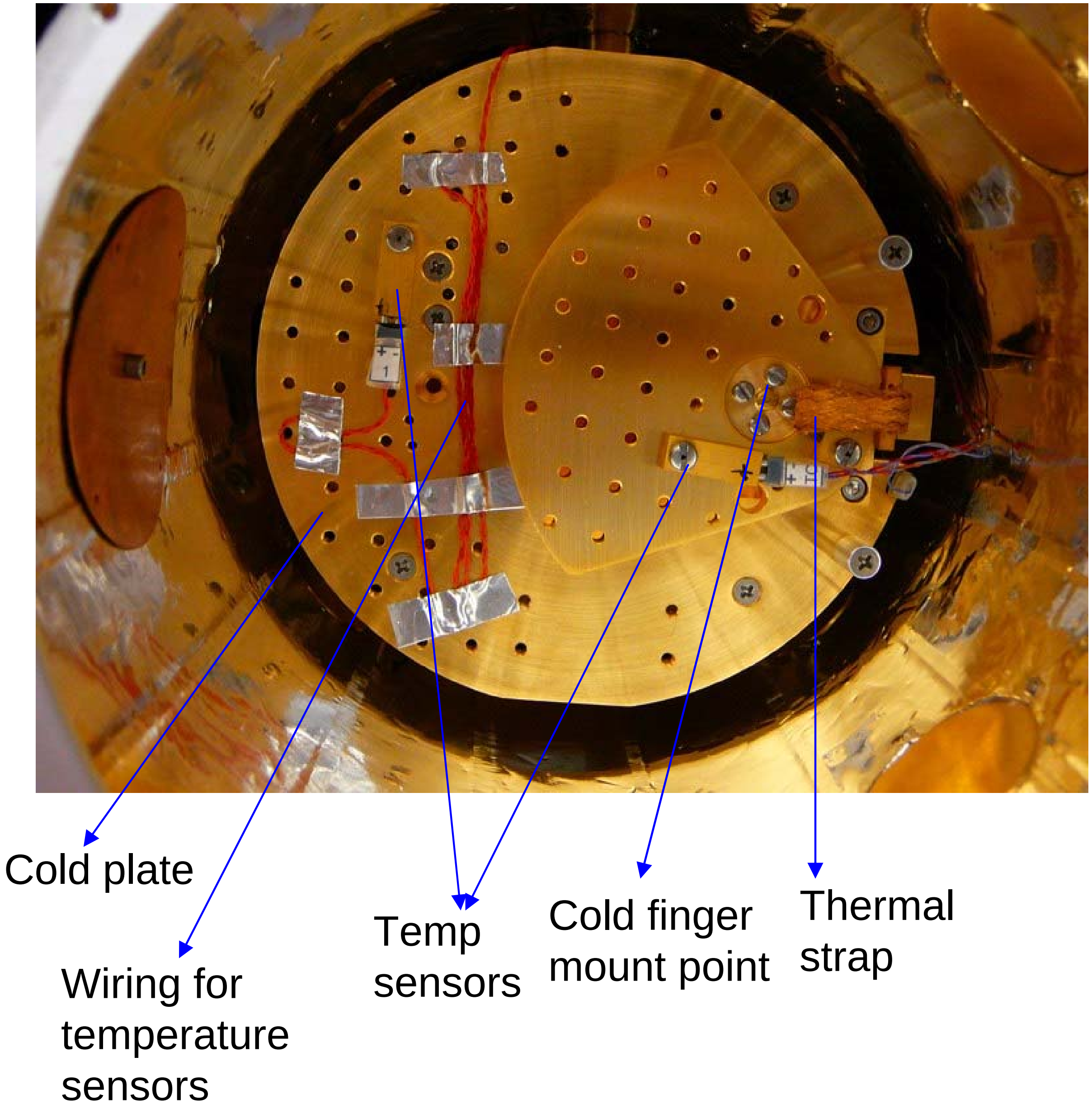


Adapter flange for beam facility

KF-40 flange (blanked out)

Dewar Rotation Stage

- Mounted on to the Dewar cold plate
- Thermal strap used for temperature transfer b/w cold plate & rotation stage
- Capable of rotating 34º on either side about vertical axis
- Equipped with detachable temperature sensor
- Cold finger to be mounted on to the central axis of rotation stage

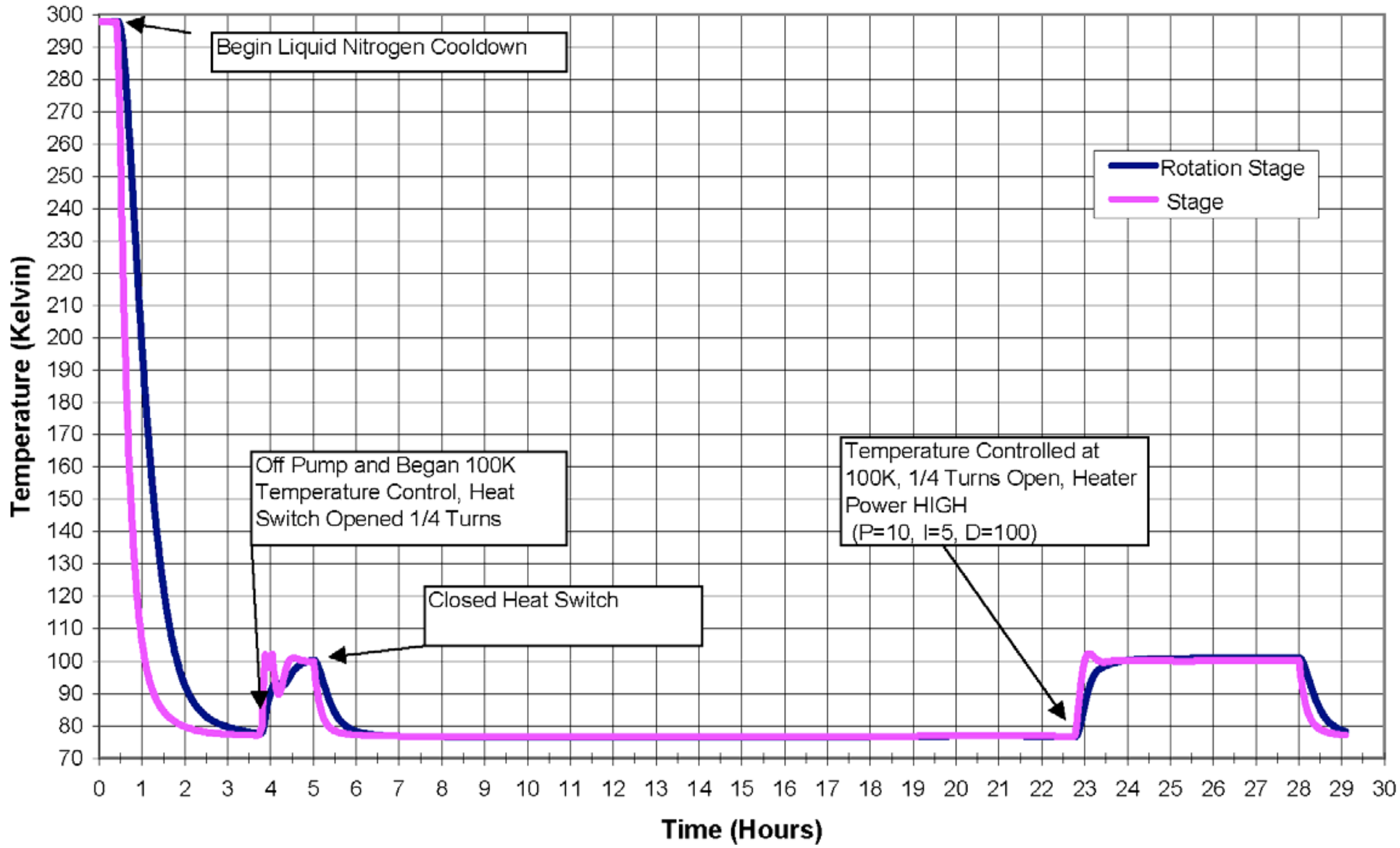


Status

- "Dewar pre-qual" in process
  - Vacuum testing
  - Mechanical tests
  - Heating tests
  - Wiring tests
  - Electrical feed-through tests
- Exploring thermal imaging
  - Aid in mapping DUT heat profiles
  - Routing the wiring to mitigate "hot spots"
- Test devices and circuits designed and fabricated (or currently in fab)

Preliminary Dewar Tests

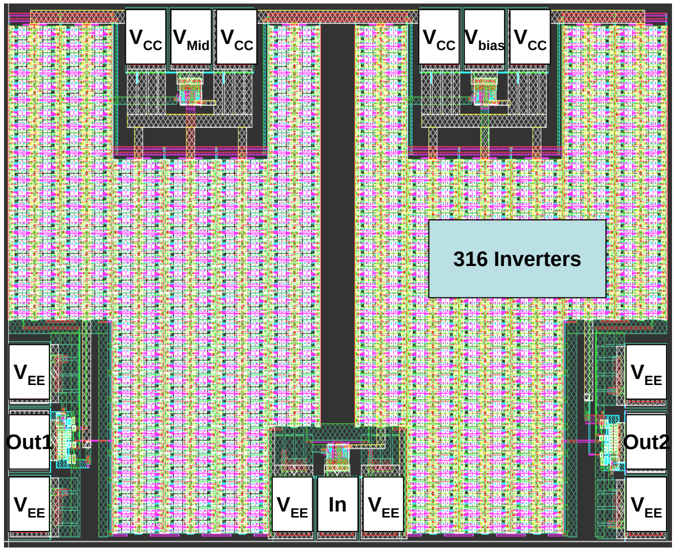
- Tests conducted at IR Labs
- “Loaded” through heat switch
- Lag seen due to thermal strap
- Mounting sensor close to DUT would avoid further lag



Hold-time tests for the Dewar’s temperature and rotation stages

Plan

- Dry-run (no beam) at test facility (Texas A&M)
- First beam tests using string of 316 inverters
  - Design of cold finger for inverter string test in process
  - CMOS and HBT versions of test circuit
  - Regular and RHBD variants
  - Quantify SE-induced pulse widths @ cryo



- Subsequent tests
  - SRAM
  - Mixed signal sub-circuit
  - Newly designed BiCMOS remote “health monitoring” unit
  - *Every experiment to have a custom-designed cold finger*

Challenges

- Wiring - optimized routing required
- # of connections
- High-speed tests
  - Matching impedances
  - "Lossless" + "flexible" cables
- "Cold-stationing" of DUT
  - Cold finger interface bonding
  - PCB design

Summary

- New system for *in-situ* SE testing at cryo designed and built
  - Portable
  - Compatible with multiple test facilities
  - Suitable for multiple technologies and operating speeds
- System characterization in process
- Tests planned to
  - Generate experimental data at cryo to aid future NASA missions
  - Provide models to use in designs
  - Validate circuit designs

Acknowledgements

- This work is supported by
  - NASA ETDP
  - NASA JPL
  - NASA GSFC & MSFC
  - DTRA
  - DARPA

  The NASA ETDP Team